Preference-based Supply Chain Partner Selection Using Fuzzy Ontology

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Supply chain management is a strategic thinking which enhances the value of supply chain and adapts more promptly for the changing environment. For the seamless partnership and value creation in supply chains, information and knowledge sharing and proper partner selection criteria must be applied. Thus, the partner selection criteria are critical to maintain product quality and reliability. Each part of a product is supplied by an appropriate supply partner. The criteria for selecting partners are technological capability, quality, price, consistency, etc. In reality, the criteria for partner selection may change according to the characteristics of the components. When the part is a core component, quality factor is the top priority compared to the price. For a standardized component, lower price has a higher priority. Sometimes, unexpected case occurs such as emergency order in which the preference may shift on the top. Thus, SCM partner selection criteria must be determined dynamically according to the characteristics of part and its context. The purpose of this research is to develop an OWL model for the supply chain partnership depending on its context and characteristics of the parts. The uncertainty of variable is tackled through fuzzy logic. The parts with preference of numerical value and context are represented using OWL. Part preference is converted into fuzzy membership function using fuzzy logic. For the ontology reasoning, SWRL (Semantic Web Rule Language) is applied. For the implementation of proposed model, starter motor of an automobile is adopted. After the fuzzy ontology is constructed, the process of selecting preference-based supply partner for each part is presented.

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1. Introduction

As market competition increases, many companies are adopting SCM (Supply Chain Management) as a key strategy for survival. Modern business competition is no longer company versus company but rather supply chain (SC) versus supply chain (Maloni and Benton, 1997). SCM is a strategy through strategic alliances between partners to reduce inventory and delivery cost and enhance the productivity of the entire supply chain. In order to achieve the expected effects of these, it is important to reduce the volatility of supply chain. Therefore, information and knowledge sharing between partners are very important.

In SCM environment, information is shared about companies' inventory levels, production planning and customer's demand. By sharing inventory among partners in supply network, a company can reduce inventory and inventory carrying cost. Also, by sharing production plan among partners, they can reduce part shortages, and adapt a quick response to the customer's needs.

In addition, SCM can protect the price break from over supply through maintaining demand and supply in the market based on monitored demand in the value chain.

Over the past years, the recall of many Toyota's brands surprised customers in the world. Recalls in the automobile industry is a fairly common practice. Recalling vehicles indicate the mark of maturity in the auto industry and its dedication to quality and regard for customer satisfaction. Toyota's recall gives a sense of the changing times in the automobile industry and the supply chain market as a whole. The lack of integration between the various entities among supply chain is a possible reason for this fiasco. Also, the over emphasis on the cost reduction for the parts is another reason for the quality problem in the Toyota's brand.

A product is made through the assembly of parts, components and subsystems. The supplier selection criteria should be varied according to the function of the parts or components. When a part is a critical component for the product quality and reliability, the partner selection criteria are focused on the quality factor than price. When demand surges suddenly with low inventory level, delivery can be an important criterion. On the contrary, if the part is a standard item, and its quality is not critical, the price is an important criterion for the supplier selection. The preferred information such as quality, delivery and price need to be shared among supply partners.

But, survey result about supply networks shows that over than second tier supplier and customers stay at the lowest utilization mode level for the common information sharing (Olhager and Selldin, 2004).

In order to share information, a new scheme is required for the automatic knowledge sharing. An ontology provides a shared vocabulary, which can be used to model a domain-that is, the type of objects and/or concepts that exist, and their properties and relations.

This research proposes an ontology model to share supply chain information among partners participating in the supply chain network. Fuzzy logic is adopted to tackle the uncertainty problem in the context and decision making variables. Through an explicit specification for a shared concept, an inference is possible in the ontology. Thus, ontology-based model is constructed for the supply partner selection using OWL (Web Ontology Language). Section 2 addresses background of this research. Section 3 proposes an ontology model and important criteria for the partner selection with preference in the fuzzy situation. Section 4 implements the proposed model for the supplier selection domain in the starter motor part at an automobile industry. Last section describes conclusions and future research directions.

2. Background

This section provides some background about the topics covered in the paper : Section 2.1 briefly overviews the SCM partnership, section 2.2 refreshes the basic ideas in fuzzy sets theory and fuzzy logic, and section 2.3 reviews the notion of ontology.

2.1 SCM Partner Selection Criteria

The criteria for supply partner selection change according to the phase of SCM implementation. Maloni and Benton (1997) proposed the supply partnership critical success factors based on the reviews of the previous research. The supply partnership critical success factors are based on five phases: throughput, initial strategic analysis phase, supplier evaluation and selection phase, partnership establishment phase and maintenance phase. For example, the criteria in the supplier evaluation and selection phase are total cost and profit benefit, cultural compatibility, financial stability, partner capability, management capability and location.

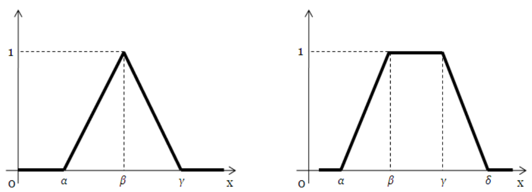
Choi and Hartley (1996) proposed eight criteria for supply partners from the survey on the purchasing managers in the auto industry. Eight criteria for supply partners are consistency, reliability, relationship, technological capability, flexibility, price and finance. They analyzed whether there exist difference in the supply network layer using MANOVA (Multivariate Analysis of Variance) technique. The result shows that two criteria have significance with the layer, but six criteria have no significance with the layer.

The sub-criteria of quality and delivery in the consistency criteria are considered critical for partners in the all layers. On the contrary, the price is considered to be not critical factor in the partner selection. This result is meaningful in other industry areas though this is induced from the auto industry. Though price is not considered to be important in the partner selection stage, it will be critical factor in the maintenance and implementation stage.

Based on the review of related researches, quality, delivery and price are chosen as the criteria for supplier network evaluation. Using the three criteria, preference-based ontology model will be developed and evaluated for the actual auto part. In the ontology model, as the addition and update of knowledge is feasible, another criteria can be easily added on the existing model. Preference-based ontology model will be discussed on Section 3.

2.2 Fuzzy Logic

Fuzzy logic (FL) suits well for trading off between significance and precision-something that humans have been managing for a very long time. FL is a convenient way to map and input space to and output space. Sets in FL do not have sharp boundaries, but there is a degree of vagueness. Let μ, $(0 \leq \mu \leq 1)$ represent the member-ship degree of the set. In the classical set, $\mu_A(x) = 1$ or 0 whether x is a member set A or not. But in a fuzzy subset A, it has the value of $0 \leq \mu_A(x) \leq 1$.



(a) (b)

<Figure 1> (a) Triangular Membership Function; (b) Trapezoidal Membership Function

Several membership functions can be used in the definition of a fuzzy set. Some of the widely used are the triangular and the trapezoidal function. A triangular function <Figure 1>(a) $tri_{\alpha,\beta,\gamma}(\chi)$ is defined over the set of non-negative reals $\mathbb{R}^+ \cup \{0\}$with $\alpha \leq \beta \leq \gamma$ being real numbers. A trapezoidal function <Figure 1>(b) $tri_{\alpha,\beta,\gamma,\delta}(\chi)$ is defined over the set of non-negative reals $\mathbb{R}^+ \cup \{0\}$with $\alpha \leq \beta \leq \gamma \leq \delta$ being real numbers.

One of the most important features of fuzzy logic is its ability to perform approximate reasoning, which involves inference rules with premises, consequences or both of them containing fuzzy propositions.

2.3 Ontologies

An ontology is defined as a formal representation of knowledge as a set of concepts within a domain, and the relationships between those concepts. It is used to reason about the entities within that domain, and may be used to describe the domain. An ontology provides a shared vocabulary, which can be used to model a domain-that is, the type of objects and/or concepts that exist, and their properties and relations. Ontologies are considered to be a proper mechanism to encode information in modern knowledge-intensive applications, so they have become one of the most used knowledge representation formalism. They allow the enrichment of data with semantics, enabling automatic verification of data consistency and making easier knowledge base maintenance as well as the reuse of components.

The OWL is a family of knowledge languages for authoring ontologies endorsed by the World Wide Web Consortium (W3C). They are characterized by formal semantics and RDF/XML-based serialization for the Semantic Web.

Recent researches on ontology are ontology matching methodology, integration of ontology and multi agent and reasoning based on fuzzy OWL. Kim et al. (2007) proposed an ontology matching methodology that determines parameters for the desired ratio of precision and recall. Ontology matching algorithm takes two ontologies as input, and finds out the matching relations between the two ontologies by using some parameters in the matching process. This research focused on the harmony of precision and recall rather than independent performance of each. Park et al. (2008) proposed a set of criteria for evaluating ontology extraction tools and evaluated them using the proposed framework.

Lee et al. (2008) reported a ubiquitous decision support system portal composed of an intelligent ontology management module and multi-agent coordination mechanism. The ontology module is designed to provide support for solving the semantic discordance to integrate heterogeneous ontology among the agents engaged in ubiquitous commerce situations. The proposed portal provides timely decision support to the involved decision entities.

Sohn and Chung (2008) proposed a user contacted environmental information with a numerical value and states using fuzzy OWL. Because the conventional method of representing context using an usual collection has some limitations in expressing the environment of the real world, this paper has chosen to use fuzzy OWL. First, user contacted environmental information is represented with OWL. Then, the OWL context is converted into fuzzy OWL. Finally, it is tested whether the automatic circumstances are possible in the fuzzy inference engine.

The W3C-endorsed OWL specification includes the definition of three variants of OWL, with different levels of expressiveness. These are OWL Lite, OWL DL and OWL Full (ordered by increasing expressiveness). Each of these sublanguages is a syntactic extension of its simpler predecessor. Though OWL Full provides most rich vocabulary, it does not guarantee inference function by DL (Description Logic). Thus, ontology-based knowledge system should be described using OWL DL vocabulary in order to have inference function.

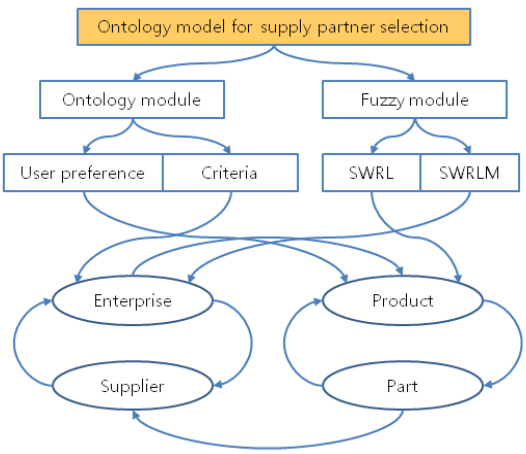
In the OWL Property, there are Object Property and Datatype Property. The former describes the object's relationship and the latter relates object with data value. In addition, there are Annotation Property and Ontology Property.

In order to perform OWL-based reasoning, W3C proposed SWRL (Semantic Web Rule Language) which is based on RuleML. It is an extension of OWL DL with XML format.

SWRL is used to reason the inferred property. SWRL was recently proposed to increase the power of OWL based ontology. Ontology architecture can be expressed using OWL, but the relationships among concepts, properties and individuals are yet to be clarified. The SWRL rules provide procedural knowledge, which compensates for some of the limitations of ontology inference, particularly in identifying semantic relationships between individuals. SWRL utilizes the typical logic expression "Antecedent → Consequent" to represent semantic rules. Each atom is attached to one or more parameters represented by a question mark and a variable (e.g., ?x). SWRL inference rules can be developed from the human comprehensible “if ⋯ then ⋯” logic which indicates the scenario of if some conditions are satisfied, then some results can be inferred. The reasoning can be performed using JESS (Java Expert System Shell), and the reasoning result can be stored in the inferred property. Also, the inferred property can be used as a parameter for a new inferred rule.

3. Fuzzy Ontology Model For SC Partner Selection

Supply chain partner selection model is composed of preference-based ontology module and fuzzy concept module. The former module is composed of the preference on the parts and partner selection criteria. The latter module evaluates the partners using SWRL and SWRLM. In the upper class, there are Enterprise and Product Class. As a subclass, Supplier and Part are attached respectively. But these subclasses can also



<Figure 2> Fuzzy Ontology Based Supply Partner Selection Model

act as an upper class for their subclass below them. In the supply chain network, first, second, third or more vendors are connected network as a chain-like structure. A fuzzy ontology model for supply partner selection is given in <Figure 2>.

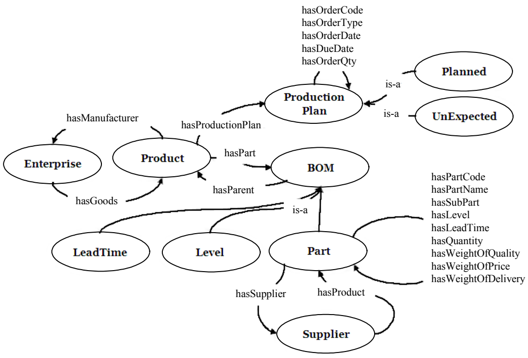
3.1 Preference-Based SC Partner Evaluation

The concept of preference has been adopted on some earlier research. Khan et al. (2010) proposed a preference-based meeting scheduler for describing the behavior of attendees. Meeting attendee expresses his/her availability in terms of preference. To satisfy user with arranging meeting, user preferences are actively accounted in this semantic meeting scheduling system. In the search system, user preference is adopted in Gursky et al. (2006).

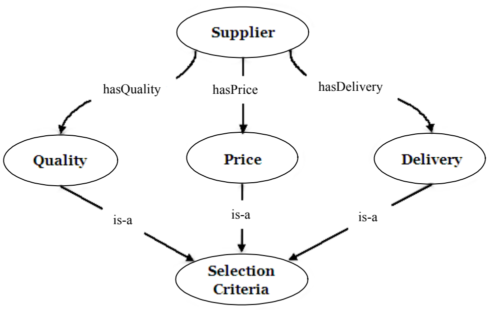
The importance of a part to be assembled into a product may vary according to its functional contribution in the product. When a part plays an important role for the product functioning or it is a critical component, the quality criteria is more preferred than other criteria. On the contrary, if the part is standard and off-the-shelf product, price criterion will be important.

Chi (2010) proposed ontology model for partner tracking in the SCM environment. In the model, enterprise, supplier, product and part are not classified as different concept. It enables inference by iterative rule based on has_product_parts property and has_parts_supplier property. It tries to track suppliers from many stages, but it cannot find partners based on priority or preferences. It suggests only potential partners for each part.

This research tries to extend Chi's research to find and recommend partners according to the status of supply chain. For that, this research assumes that each part has its own preference. The concept of enterprise and supplier, and the concept of product and part are classified respectively. Each partner in the supply network has its own position as an enterprise, and can construct its supply network as a sub class. Following this concept, the SC partnership ontology model is represented in <Figure 3>.



(a) Part Preference Ontology



(b) Supplier Evaluation Ontology

<Figure 3> Preference-Based SC Partnership Ontology Model

In the ontology relationship, two relationship types, "is-a" and "has-a" are defined. "is-a" represents that one concept is a subclass of another. In <Figure 3>(a), "LeadTime" is a sub concept of "BOM." "has-a" represents a composing relationship that one concept belongs to another concept. The end points of arrow connect both domain and range respectively. For example, "hasGoods" property relates "Enterprise" concept and "Product" concept as domain and range.

Enterprise concept implies a company assembling a finished product using more than one component from suppliers. Supplier concept means a company producing components of a product and supplies them to an enterprise. In the ontology, necessary and sufficient condition can be described to specify these concepts explicitly.

$$Enterprise \equiv Company \sqcap \forall hasGoods.Product$$
$$Supplier \equiv Company \sqcap \forall hasProduct.Part$$

The proposed model composed of Enterprise and Supplier can be applied to various supplier hierarchies. Suppose a company which assembles several parts into a component and supplies it to an enterprise which produces a finished product. For the supplier's point of view, the component is a final product though it may be only a part from the enterprise's point of view. This implies that the supply chain may constitute a hierarchy with several layers. The company which produces the component can be an enterprise with its suppliers connected to itself. PSM

(Problem Solving Method) provides the role between Enterprise and Supplier. The detail of PSM is not covered in this paper.

In order to represent part preference, preference concept is adopted. Each part has seven point measure with **hasWeightOfQuality**, **has WeightOfD eliver** and **hasWeightOfPrice** as an Object Property. Also, supplier can be evaluated using **selection criteria concept**. Each supplier has Object Property with **hasQuality**, **hasPrice** and **hasDelivery**. The selection criteria such as Quality, Price and Delivery has three point measure of Excellent, Good, Poor instance.

Among the selection criteria proposed in the Choi and Hartley (1996) and Maloni and Benton (1997), three criteria are chosen for demonstration. OWL-based Ontology is represented as XML (eX tended Markup Language) format. XML enables knowledge sharing, reuse and knowledge addition much better than in Expert System. The output of this model makes it possible to add more criteria on top of the three when this model is verified its efficiency. In order to implement the ontology model, Protégé[1] is adopted as an ontology editor.

3.2 Fuzzy Model

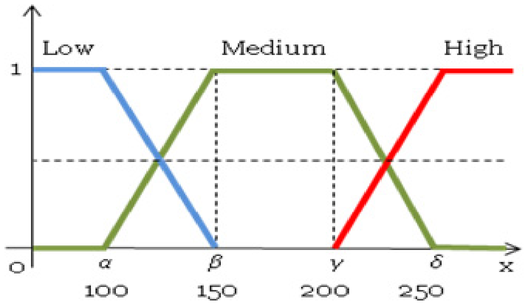
Recently, fuzzy logic based ontology reasoning is proposed in some areas. Trappey et al. (2009) reported fuzzy ontology-based document clustering approach in the domain of patent. Bobillo et al. (2009) proposed Protégé and OWL based semantic fuzzy expert system using Jess (Java Expert System Shell), FuzzyJess[2] and Fuzzy rules. Linguistic Label is adopted for Fuzzy Class. Decision making variables have hasValue and hasLabel as Datatype property. Chorbel et al. (2007) proposed Fuzzy model using Fuzzy Meta Class. The two researches use similar methodology except the latter research uses Object properties as hasLabel.

In this research, the quantitative factors such as quality, delivery and price are transformed into linguistic label using fuzzy membership function. The purchaser's preference for the three factors is measured using seven point scale based on fuzzy membership function.

When quality preference is most important, quality factor is highly considered in the selection process. But in this case, other factors are considered with less priority. Though quality preference is high, but suppliers have similar quality level, other factor can be a decision criterion. For example, the quality is most important factor, and its required level is higher than γ in <Figure 4>. When the quality level QL(χ_i) of partner χ_i is $\gamma < QL(\chi_i) < \delta$, the quality criteria plays an important role in the selection process. When the quality level QL(χ_i) of partner χ_i is QL(χ_i)$\geq \delta$, other criteria will be critical in the partner selection. Thus, preference-based partner selection process can be represented using fuzzy membership function.

1) Protégé : http://protege.stanford.edu.

2) Jess, FuzzyJess : http://www.jessrules.co.



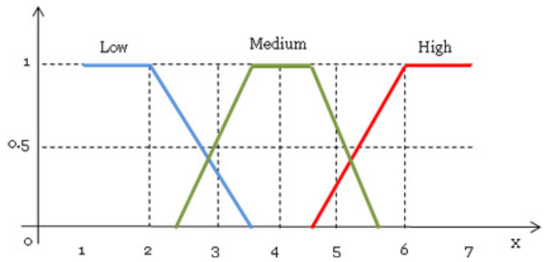
<Figure 4> Fuzzy Membership Function for Quality Factor

<Figure 4> shows a fuzzy membership to transform quantitative quality level into linguistic label. Suppose the quality level of supplier is 220. The probability with medium quality level is 0.4, and the probability with high quality level is 0.6. In the fuzzy reasoning, the quantitative data is transformed into linguistic label using SWRL, and the mathematical operation is performed using SWRLM which is a mathematical extension of name space from SWRL.

SWRLM is a library with Mathematical Expressions for SWRL. It supports mathematical functions such as *sqrt, log* and *eval*. In the SWRLM, *eval* function describes expression, and transfers parameters to the variable combined with Java Math Expression Parser. Suppose that *?x* and *?y* are parameters needed for the operation. From the qualitative data, the probability to be used in the fuzzy membership function can be acquired from Swrlm:eval. The Swrlm:eval returns a value from the following equation.

*Swrlm:eval(?r, "(57*x)/y)", ?x, ?y)*

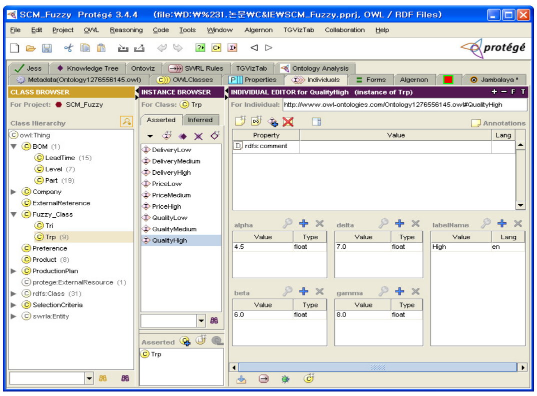
<Figure 5> shows seven point scale of fuzzy membership function for the buyer preference representation.



<Figure 5> Membership Function of Preference

This research proposes a fuzzy ontology model for SC Partnership as shown in <Figure 6>. Ontology model consists of "class", "property" and "individual", which correspond to "concept", "attribute" and "instance."

Fuzzy class is adopted in the model. Fuzzy class has fuzzy set with a membership function specified by a triangular or trapezoidal function. It has five data type properties-the parameters of the membership function (**alpha**, **beta**, **gamma**, **delta**)-and a text property (**labelName**). Each Part has a Datatype properties **hasLabel**.



<Figure 6> Supply Chain Partner Selection Ontology

3.3 Swrl Reasoning Rule

In this research, each individual and corresponding function are represented for fuzzification. Thus, each function for the preference of price, delivery and quality is represented differently. For example, the range of each function can be varied for fuzzification;

$$Quality_{High} = Trp_{5,6,7,8},\ \ Price\ _{High} = Trp_{4,5,7,8}$$

<Table 1> represents reasoning rule of SWRL for fuzzification.

<Table 1> SWRL Reasoning Rule

Reasoning rule	SWRL syntax
FR_ Delivery _04	*Part(?x) ^ hasDeliveryPreference(?x, ?y) ^ hasFuzzyConcept(?x, ?z) ^ labelName(?z, "Medium") ^ alpha(?z, ?a) ^ beta(?z, ?b) ^ swrlb:greaterThan(?y, ?a) ^ swrlb : lessThanOrEqual(?y, ?b) ^ swrlm : eval(?c, "1/(bet-alp)*(y-alp)+1", ?b, ?a, ?y) → hasProbDelivery_Medium(?x, ?c)*
FR_ Price _06	*Part(?x) ^ hasPricePreference(?x,?y) ^ hasFuzzyConcept(?x,?z) ^ labelName(?z, "Medium") ^ beta(?z, ?a) ^ delta(?z, ?b) ^ swrlb:greaterThan(?y, ?a) ^ swrlb : lessThanOrEqual(?y, ?b) → hasProbPrice_Medium(?x, 1.0)*
FR_ Quality _10	*Part(?x) ^ hasQualityPreference(?x, ?y) ^ hasFuzzyConcept(?x, ?z) ^ labelName(?z, "High") ^ beta(?z, ?a) ^ swrlb : greaterThan(?y, ?a) → hasProbQuality_High(?x, 1.0)*

The reasoning process of FR_Delivery_04 works as the following. First, it searches for Delivery Preference for Part *x*. Datatype property of **hasDeliveryPreference** is integer type. Then, it searches for fuzzy value for the preference of Part *x*. In the fuzzification, there are preference for the quality, price and delivery and its corresponding value of *alpha, beta, gamma, delta*. In order to decide the range for the preference, the condition *labelname (?z, "Medium")* is added. This implies that the delivery preference with medium is adopted in order to calculate a probability. SWRLM namespace is used to represent the equation for the probability of Trapezoidal membership function. When all conditions are satisfied, the probability with medium preference is reasoned through the process. The other reasoning rules correspond to the case with zero slope, and their reasoning rules are rather simply represented.

This fuzzification process is applied for the purchaser's preference and supplier's level of quality, delivery and price. Supplier's grade can be evaluated based on the probability from fuzzification.

3.4 Preference-Based SC Partner Selection Model

The proposed model gets 7 point input about user preference. This value is defuzzified between [0, 1] value through fuzzy membership function. Also, fuzzy membership function is defined for each part. The probability is generated to relate quality, delivery and price factor with user preference.

The partner selection criteria are based on the value from the user preference and decision criteria (Quality, Delivery, Price) by a supplier. The smaller one of the difference between the two values can be the best supplier. This means that difference between the purchaser's expectation level and supplier's service level about quality, price and delivery is measured. A supplier is selected with the minimum difference.

The evaluation score for each partner is assumed as the following.

$$\sum_{i}^{n} |UP_i - SC_i|$$

where
UP_i : User Preference value for evaluation item *i*.
SC_i : Supplier value for evaluation item *i*.

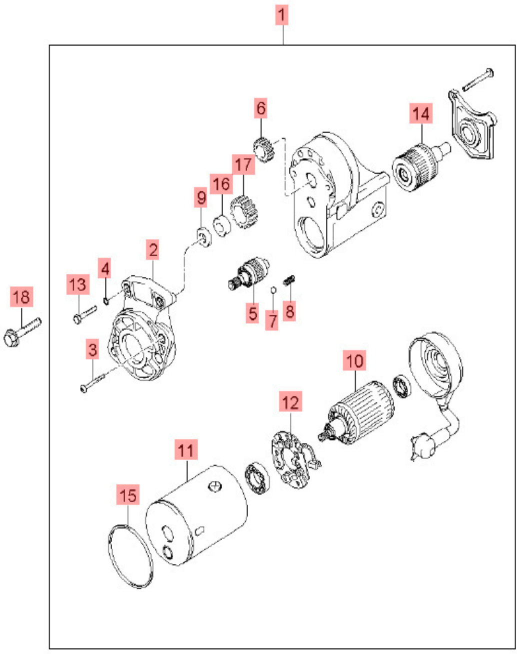
In the past, the supplier with a lower price has been considered as the better partner. But in the supply chain network, the lowest price does not always guarantee the best partner. Delivery date should not be earlier or later than the target date but be exactly on the assigned date. The quality factor is assumed as a necessary condition. When quality satisfies the required level, it is not critical factor for supplier selection.

4. Implementation

4.1 Problem Domain

SC partnership ontology model is applied in the auto industry. Among many components of an automobile, a starter motor is chosen as an implementation domain.

The components of a starter motor assembly are shown in <Figure 7>. Starter motor is a key component for starting a car. Among the 18 components, part number 10, 12 and 14 are the most important part for quality criteria for their magnetic property. In the starter motor case, high pressure is not transferred in the housing. Thus, for the screws and nuts for housing assembly, price or delivery can be preferred criteria than quality because they are standard parts and can be purchased from the off-the-shelf of hardware stores.



<Figure 7> Starter Motor Assembly Structure

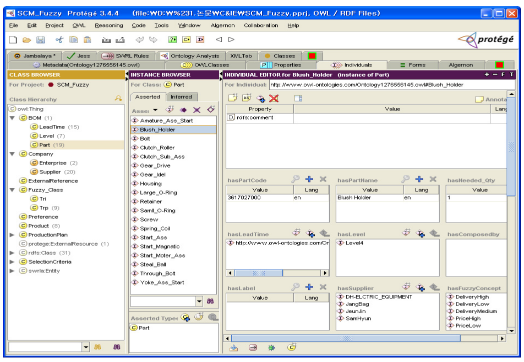
For the ontology model, 20 suppliers, eight products, and 18 parts are chosen as individual. And their values are input in the model. <Table 2> shows Bill of Material (BOM) from the starter motor assembly.

<Table 2> BOM from Starter Motor Assembly

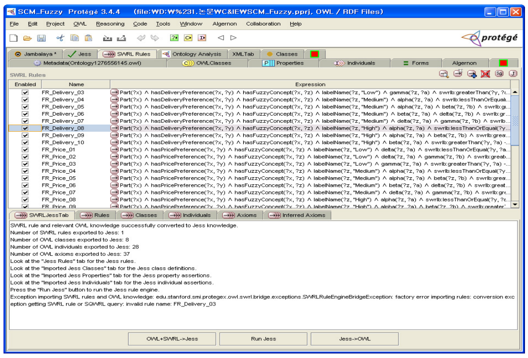
Seq	PartCode	PartName	Qty	Level	Lead Time
1	3610027010	Start Assembly	1	1	14
2	3611027000	Housing	1	2	7
3	3613527000	Screw	2	3	2
4	3613727000	O Ring	2	3	2
5	3613927000	Clutch Sub Ass.	1	3	7
6	3614127000	Gear Drive	1	3	2
7	3614227000	Steel Ball	1	3	2
8	3614327000	Spring Coil	1	3	2
9	3614527000	Retainer	1	3	2
10	3615027000	Amateur Ass. Starter	1	4	7
11	3616027000	Yuke Ass. Starter	1	3	7
12	3617027000	Blush Holder Ass.	1	4	7
13	3618427000	Screw Bolt	2	3	2
14	3612027010	Start Magnetic	1	3	7
15	3613727010	O Ring	1	4	2
16	3613927010	Clutch Roller	5	3	2
17	3614127010	Gear Ideal	1	3	2
18	1140410653	Bolt	2	3	2

4.2 Implementation On The Protégé

For the implementation of SC partnership ontology model, Protégé is adopted. <Figure 8> shows ontology model using Protégé editor. <Figure 9> shows SWRL-based reasoning rule.

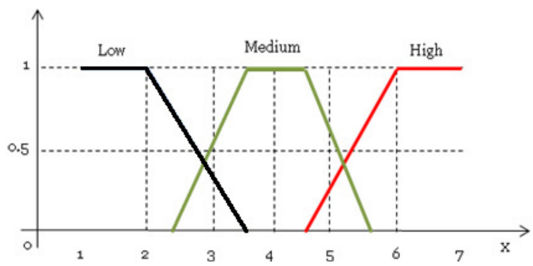


<Figure 8> Supply Chain Partner Selection Ontology in the Protégé Editor



<Figure 9> SWRL-Based Reasoning Rule

Let's illustrate an example of a Gear Drive. As Gear Drive does not generate high torque and it is a standard part, its preference is assumed as {Quality Preference = 2; Delivery Preference = 5; Price Preference = 7}. The membership function for the Gear Drive is assumed as <Figure 10>. The user preference for three criteria can input as {Quality Low = 1, DeliveryMedium = 0.5, PriceLow = 1}. The Fuzzy membership function for Gear Drive is given in <Table 3>.



<Figure 10> Membership Function of Preference

<Table 3> Fuzzy Membership Function

	Quality	Delivery	Price
High	$trZ_{18, 20, 22, 24}$	$trZ_{2, 3, 4, 5}$	$trZ_{5, 5, 6, 6, 5, 7}$
Medium	$trZ_{15, 15, 18, 20}$	$trZ_{4, 5, 6, 7}$	$trZ_{4, 5, 5, 5, 5, 6}$
Low	$trZ_{8, 11, 13, 15}$	$trZ_{6, 7, 8, 9}$	$trZ_{3, 5, 4, 4, 5, 5}$

<Table 4> Score of Supplier

Supplier	Quality	Delivery	Price	Supplier Score
DongNam	17	7	6.8	$\mu_{QualitysLow}=0$ $\mu_{DeliveryIsMedium}=0$ $\mu_{PriceIsLow}=0$
HanSong	14	5	4.75	$\mu_{QualitysLow}=0$ $\mu_{DeliveryIsMedium}=1$ $\mu_{PriceIsLow}=0.5$
Metia	25	8	7.5	$\mu_{QualitysLow}=0$ $\mu_{DeliveryIsMedium}=0$ $\mu_{PriceIsLow}=0$
NamYang	10	4.5	4.6	$\mu_{QualitysLow}=1$ $\mu_{DeliveryIsMedium}=0.5$ $\mu_{PriceIsLow}=0.8$

The score of three criteria among supply partners for Gear Drive is given as <Table 4>. The process for calculating partner's score follows the criteria given in section 3. Suppose the purchaser's quality level is (QualityLow = 1). In the <Table 4>, consider the case of DongNam. The fuzzified value of DongNam in quality is ($\mu_{QualityIsLow}=0$). For the quality factor, the difference between requirement and supply is 1 ([QualityLow = 1]-[$\mu_{PriceIsLow}=0$] = 1). For the price factor, required price level is (PriceLow = 1). The fuzzified value of DongNam in price is ($\mu_{PriceIsLow}=0$). The difference in price is 1. For the delivery factor, buyer requirement is given as (DeliveryMedium = 0.5). Thus, the difference in delivery is 0.5. Finally, for the case of Dong Nam, sum of difference is 2.5. Using the same process, the scores for the other suppliers can be calculated. Finally, the score of each supplier is derived as {DongNam = 2.5, Hansong = 2.0, Metia = 2.5, NamYang = 0.2}. Among these, the case of NamYang shows the lowest value, and NamYang is chosen as the final supplier.

5. Conclusions And Future Works

This research proposes a preference-based fuzzy ontology model for supply partner selection. Fuzzy membership function is adopted for the representation of user preference. The membership of each part is defined using hasValue property. The decision criteria such as Quality, Delivery and Price are defuzzified. User preference with probability and defuzzified result from suppliers is adopted for partner selection criteria. This model is applied for the partner selection in the domain of starter motor part from the automobile component.

The following areas are required for the future research.

First, to automate the whole process, data mining technique is required for the determination of membership function.

Second, input process of the user preference needs grouping through functional classification of parts. Explicit declaration of a concept and its upper and lower relationship is a good application domain of ontology. The classification ontology of part function and BOM ontology with preference can reduce the efforts of manual input in the pre-processing step in the ontology model.

Third, a comparative study between the results from ontology model and actual decision making in the real industry is required to verify the credibility of the model.

References

Bobillo, F., M. Delgado, J. Gomez-Romero and E. Lopez, "A Semantic Fuzzy Expert System for a Fuzzy Balanced Scorecard", *Expert Systems with Applications*, Vol.36(2009), 423～433.

Chi, Y.-L., "Rule-based Ontological Knowledge base for Monitoring Partners across Supply Networks", *Expert Systems with Applications*, Vol.37, No.2(2010), 1400～1407.

Choi, T. Y. and J. L. Hartley, "An Exploration of Supplier Selection Practices across the Supply Chain", *Journal of Operations Management*, Vol.14(1996), 333～343.

Chorbel, H., A. Bahri and R. Bouaziz, "Fuzzy Protégé for Fuzzy Ontology Models", 11th Intl, Protégé Conference, Amsterdam, Netherlands, http://protege.stanford.edu, 2009.

Gursky, P., T. Horvath, R. Novotony, V. Vanekova and P. Vojtas, "UPRE : User Preference based Search System", IEEE/WIC/ACM International Conference on Web Intelligence (WI), Hong Kong, China, (2006), 841～844.

Khan, M. A., F. Nawaz, H. F. Ahmad and K. Latif, "Preference-Based Meeting Scheduler using Ontology", working paper, 2010.

Kim, W., S. Ahn, J. Kang and S. Park, "Adaptive Ontology Matching Methodology for an Application Area", *Journal of Intelligent Information Systems*, Vol.13, No.4(2007), 91～104.

Lee, H., K. Lee and M. Sohn, "Intelligent Integration of Ontology and Multi-agents Coordination Mechanism in Ubiquitous Decision Support System Portal", *Journal of Intelligent Information Systems*, Vol.14, No.1(2008), 47～66.

Maloni, M. J. and W. C. Benton, "Supply Chain Partnerships : Opportunities for Operations Research", *European Journal of Operational Research*, Vol.101(1997), 419～429.

Olhager, J. and E. Selldin, "Supply Chain Management Survey of Swedish Manufacturing Firms", *Int. J. Production Economics*, Vol. 89(2004), 353～361.

Park, J., W. Cho and S. RHo, "Measurement Criteria or Ontology Extraction Tools", *Journal of Intelligent Information Systems*, Vol.14, No.4 (2008), 69～87.

Sohn, J. and I. Chung, "Representation and Reasoning of User Context Using Fuzzy OWL", *Journal of Intelligent Information Systems*, Vol.14, No.1(2008), 35～45.

Trappey, A., C. Trappey, F. Hsu and D. Hsiao, "A Fuzzy Ontological Knowledge Document Clustering Methodology", *IEEE Transactions on Systems, Man and Cybernetics-Part B : Cybernetics*, Vol.39, No.3(2009), 806～814.

Abstract

퍼지 온톨로지를 이용한 선호도 기반 공급사슬 파트너 선정

이해경* · 고창성** · 김태운**

공급사슬관리(SCM)는 공급사슬의 가치를 높이고 변화하는 환경에 더 민첩하게 적응할 수 있는 전략적인 접근방식이다. 공급사슬 파트너 간에 중단 없는 파트너쉽과 가치 창출을 위해서는 정보와 지식의 공유 및 적절한 파트너 선정기준이 적용되어야 한다. 따라서 파트너 선정 기준은 제품의 품질과 신뢰도를 유지하기 위해서 아주 중요하다. 제품의 각 부품은 적절한 공급 파트너를 통해서 공급된다. 파트너를 선정하는 기준은 기술적 능력, 품질, 가격, 지속성 등 여러 요인이 있다. 실제로 파트너 선정기준은 구성부품의 특성에 따라서 변화할 수 있다. 그 부품이 핵심 구성품이면 품질이 가격에 비해서 최고 우선순위가 된다. 표준부품은 낮은 가격이 우선순위를 가진다. 간혹 긴급 주문과 같은 예기치 못한 상황이 발생하면 우선순위가 변하게 된다. 따라서 SCM 파트너 선정 기준은 구성부품의 특성과 상황에 따라서 동적으로 결정 되어진다. 이 연구의 목적은 상황과 부품의 특성에 따라서 공급사슬 파트너쉽을 위한 온톨로지 모델을 제시하고자 하는 것이다. 변수의 불확실성은 퍼지이론을 이용하여 나타내고자 하였다. 부품별 우선순위와 상황변수는 웹 온톨로지 언어(OWL : Web Ontology Language)를 이용하여 모델링 하였다. 부품의 우선순위는 퍼지로직을 이용한 퍼지소속함수로 변환 되어진다. 온톨로지의 추론을 위해서 SWRL (Semantic Web Rule Language)을 이용하였다. 제안된 모델의 구현을 위해서 자동차 구성품인 스타트모터 부품을 대상으로 온톨로지를 구축하고 구성 부품별 우선순위에 따른 공급 파트너를 선정하는 과정을 제시하였다.

Keywords : 퍼지 온톨로지, 퍼지로직, 공급파트너 선정, 우선순위, OWL, SWRL

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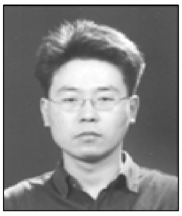

이해경
경성대학교 산업공학과 학사, 동대학원 산업시스템공학과 석사학위를 취득하였으며, 현재 동대학원 산업시스템공학과 박사과정 중이다. 관심분야는 인공지능, 정보시스템, 온톨로지, Semantic Web 등이다.

고창성
현재 경성대학교 산업경영공학과 교수로 재직 중이다. 서울대학교 산업공학과에서 학사, 한국과학기술원 산업공학과에서 석사, 박사학위를 취득하였다. 관심분야는 물류관리, 공급사슬경영 등이다.

김태운
현재 경성대학교 산업경영공학과 교수로 재직 중이다. 서울대학교 산업공학과에서 학사, 한국과학기술원 경영과학과에서 석사, 펜실베니아 주립대학교 산업공학과에서 박사학위를 취득하였다. 2011년도 현재 미국 NIST Manufacturing Systems Integration Division에 방문교수로 머물고 있다. 관심분야는 제품가족설계, 온톨로지 모델링, Supplier Discovery 등이다.